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Autonomic and behavioral responding to concealed information: Differentiating orienting and defensive responses

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Abstract

A mock crime experiment was conducted to examine whether enhanced responding to concealed information during a polygraph examination is due to orienting or defensive responding. Thirty-six undergraduate students enacted one of two mock crimes. Pictures related to both crimes were presented while heart rate, magnitude of the skin conductance response, and reaction times to a secondary probe were measured. Compared to control pictures, participants showed heart rate deceleration and enhanced electrodermal responding to pictures of the crime they had committed. Probe reaction times did not differ significantly between crime and control pictures. The present findings support the idea that the orienting reflex accounts for the enhanced responding to concealed information. Theoretical and practical implications of the orienting account are discussed.

Descriptors: Concealed information test, Defensive response, Orienting response, Probe reaction time, Guilty knowledge, Deception

In this study, we examined whether orienting can account for enhanced physiological responding to concealed information during a polygraph examination. During the concealed information test (first described by Lykken, 1959, and named by him the "guilty knowledge test"[1]), participants are presented with a series of multiple-choice questions, each having one correct (crime-relevant) and several incorrect items. For example, if the crime under investigation involved a bank robbery, a concealed information question could be: "If you have committed the robbery, then you know in what kind of car the robbers got away. Was the car (a) a yellow Toyota, (b) a grey Honda, (c) a red Opel, (d) a green Renault, or (e) a blue Peugeot?" If the interrogee systematically responds more strongly to the correct item than to the control items, he or she is supposed to have secret information about the crime. Using five or more concealed information questions, each embedded within an appropriate set of control items, it is unlikely that an innocent suspect will systematically react more strongly to the correct answers. Reviews of the concealed information test have pointed out that this test is very accurate under controlled laboratory conditions (Ben-Shakhar & Elaad, 2003; MacLaren, 2001).

Despite the accuracy of the concealed information test, two questions remain largely unanswered. First, the effectiveness of this test in field situations is unknown. Out of more than 100 articles on the concealed information test, only two have examined the applicability of the concealed information test in real-crime situations (Elaad, 1990; Elaad, Ginton, & Jungman, 1992). Both studies confirmed the high specificity of the concealed information test, in that the innocent suspect has a small chance of being mistakenly classified as "guilty." However, results on the sensitivity were less positive: Only between 65% and 76% of the guilty suspects were classified correctly. One reason for the low sensitivity may be the small number of questions used. Both studies used an average of 1.8 to 2 concealed information questions, whereas 5 or more questions are recommended. In a recent meta-analysis, Ben-Shakhar and Elaad (2003) demonstrated that the number of questions is the most important factor moderating the accuracy of the concealed information test. Second, the underlying theory of the concealed information test has not been systematically investigated. Research aimed at understanding the processes underlying physiological detection of deception is scarce (National Research Council, 2002). Yet, the concealed information test may only be regarded as scientific evidence in court if its theoretical

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[1]We prefer the term Concealed Information Test, because this paradigm has interesting applications outside the forensic practice. For example, the concealed information test has been used as an implicit test of recognition in patients suffering from amnesia (Verfaellie, Bauer, & Bowers, 1991).

foundations prove to stand the test of falsification (Ben-Shakhar, Bar-Hillel, & Kremnitzer, 2002). It has been argued that enhanced orienting accounts for the differential responsivity to concealed information (Lykken, 1974). The present study reviews the available evidence for and provides a direct test of the orienting hypothesis.

The orienting reflex (OR) plays a crucial role in information processing. According to Sokolov (1963), during the repeated processing of sensory information, a mental model of the surrounding world is gradually built. All incoming sensory information is then compared to that model. If a mismatch between the neuronal model and the incoming stimulus is detected, a novelty OR is elicited. If the stimulus matches the existing model, the OR is inhibited and habituation takes place. An exception to this process occurs whenever stimuli are tagged as significant. Then, a match between the stimulus and the mental representation will elicit a significance OR. Notwithstanding some exceptions, extensive research has generally produced data in support of Sokolov's comparator model (Öhman, Hamm, & Hugdahl, 2000). Following this model, it is reasonable to assume that presentation of crime information will elicit a significance OR in guilty individuals. Only for them, the correct answer has a special meaning and will lead to enhanced physiological responding. For persons without knowledge about the crime under investigation, all items should be homogeneous, thereby minimizing the chance of distinct responding to the crime details. Indeed, elaborate research has demonstrated that innocent persons have only a small chance of reacting consistently more strongly to the correct items in the concealed information test (MacLaren, 2001).

Reviewing the literature, we found five arguments suggesting that enhanced orienting may be the active mechanism of the concealed information test. First, both physiological and behavioral indicators of the OR have been shown to be useful in detecting concealed information. Using the skin conductance response, Lykken (1959) was able to differentiate most guilty from innocent subjects (90% correct classifications). This finding has been replicated numerous times across different laboratories (see Ben-Shakhar & Elaad, 2003). Other physiological and behavioral measures are also able to distinguish knowledgeable from uninformed participants: Among these are pupil dilation (Lubow & Fein, 1996), event-related potentials (Rosenfeld et al., 1988), and reaction times (Verschuere, Crombez, & Koster, in press). These measures can be usefully integrated within an orienting framework. Second, a core feature of the OR is that the magnitude of the response diminishes with repeated presentation. Likewise, habituation of the skin conductance response has been frequently reported in research on the concealed information test. For example, Ben-Shakhar, Frost, Gati, and Kresh (1996) reported a marked decrease in responsivity from the first to the second presentation of concealed information.

Third, OR generalization was demonstrated in the concealed information test. For example, in the study by Ben-Shakhar et al. (1996), undergraduates were asked to memorize the details of a crime and to hide possession of this knowledge in a subsequent concealed information polygraph test. In four experiments, they examined to what extent OR generalization takes place to stimuli that were semantically related to the crime details. Partial generalization was found between the crime stimulus and its synonym or its semantic superordinate. Complete generalization occurred when the crime stimulus was presented in a different sensory modality (i.e., word–picture). Fourth, although emotional (e.g., anxiety) and motivational variables (e.g., the motivation to deceive) may increase physiological responding to concealed information, several studies have shown that recognition of concealed information is sufficient to create differential responding. This indicates that the concealed information test is based on cognitive rather than emotional/motivational factors (Ben-Shakhar & Furedy, 1990). And fifth, Verschuere et al. (in press) recently demonstrated that the concealed information effect is related to the significance of the concealed information stimuli. To disentangle the effects of familiarity and significance in the concealed information test, we created a condition existing of familiar, nonsignificant stimuli ("mere knowledge items"). In three experiments, we found greater reaction-time slowing to concealed information compared to mere knowledge items. Again, this finding is supportive of the idea that orienting to significant stimuli is the underlying mechanism of the concealed information test.

Despite the arguments in support of the OR hypothesis, alternative theories and differential prediction have not been investigated. Until now, all theoretical proposals for the concealed information test have been formulated in terms of orienting. However, enhanced responding to concealed information might also be explained in terms of the defensive reflex (DR). The purpose of this reflex is to protect the organism from aversive stimuli (Sokolov, 1963). In the context of lie detection, it is plausible that guilty suspects will seclude themselves from (stimulus rejection) rather than orient toward (stimulus intake) crime details. Therefore, the behavioral and physiological responses to concealed information stimuli may be considered correlates of the DR instead of the OR. The OR–DR dichotomy needs, however, some qualification. First, though the DR seemingly contrasts sharply with the OR, it has nevertheless been proven difficult to distinguish both responses (Graham, 1979; Turpin, 1986). Both systems share several response components (e.g., skin conductance response), and other components have been much debated (e.g., peripheral and central vascular responses). Heart rate has, however, been proposed as an easily measured and reliable criterion to distinguish both response systems (Graham & Clifton, 1966). Orienting was identified with heart rate deceleration, whereas defensive responding was argued to be associated with acceleration. Although challenged by some (e.g., Barry & Maltzman, 1985), extensive research supports this hypothesis (see, e.g., Cook & Turpin, 1997). Second, Lang, Bradley, and Cuthbert (1997) have argued that defense involves stages of responding, obtaining physiological responses consistent with orienting with moderate activation of the defense system. We elaborate on their defense cascade model in the Discussion section.

Objectives and Predictions of the Present Study

The aim of the present study is to investigate whether the concealed information test is based upon orienting or defense. To differentiate between both reflexes, heart rate was measured. Furthermore, electrodermal responses and probe reaction times were also measured. Using a mock crime procedure, all participants committed one of two mock crimes and were unaware of the other crime. The mock crime consisted either of stealing 10 euro or committing exam fraud. The subsequent concealed information test was a modification of the secondary reaction-time paradigm. This procedure has proven to be a useful tool for the combined examination of physiological responding

and the allocation of attention (for a review, see Siddle, 1991). In the present study, participants were shown pictures of both crimes while heart rate and electrodermal responding were measured. Secondary auditory probes were presented from time to time, and response latencies in tone detection were registered. We predicted that crime pictures would lead to enhanced electrodermal responding and slowing of probe detection. Of most importance to this study was the heart rate. According to the OR hypothesis, heart rate was expected to decelerate in response to crime pictures in participants with crime knowledge. In contrast, the DR hypothesis would predict heart rate acceleration.

Methods

Participants

Thirty-six first-year psychology students (29 women, 7 men) at Ghent University took part in the experiment in partial fulfillment of course requirements.

Stimuli

The experimental stimuli were 12 digital color pictures (height: 95 mm; width: 127 mm), consisting of six details of each crime. Details on which pictures served as crime details are underlined in the Procedure section.

Apparatus

The experiment was conducted in a sound-attenuated, darkened laboratory that was connected via intercom and a one-way vision screen to an adjacent control room. A Lablinc V Coulbourn recorded skin conductance and heart rate. Skin conductance was measured using a constant voltage (0.5 V) coupler and Ag/AgCl electrodes (0.8 cm diameter) filled with KY jelly that were attached on the thenar and hypothenar eminences of the left hand. Heart rate was obtained by attaching a photoelectric transducer to the left index finger. The skin conductance and heart beat signals were recorded on a second PC, equipped with a Scientific Solutions Labmaster DMA card, running VPM software (Cook, 1997).

All stimuli were presented using Inquisit 1.33 (2002). The auditory stimulus was a 1000 Hz tone, presented during 500 ms at 71 dB by means of a headphone. Participants were seated approximately 50 cm from the screen.

Procedure

Participants were informed by a first experimenter that they took part in a lie detection experiment and were provided with information about use and validity of the polygraph ("lie detector"). Next, they were asked to choose one of two envelopes, which allocated them to either the theft group or the exam fraud group.

Participants enacting the theft ($n = 18$) were instructed to enter a nearby room using a key with a toy key ring. Access to the room is known to be only permitted to professors. In this room they had to look for a gray coat and to steal 10 euro out of a red wallet inside that coat. Participants were asked to leave the gray gloves that they had used, before returing to the laboratory. Participants simulating the exam fraud ($n = 18$) were asked to gain access to a storage room on another floor using a key with a red key ring. In this room they had to open a suitcase, which contained a file. They were asked to open this green file, copy the answers of the red exam form. Before returning to the laboratory, participants were asked to leave a drink that they had taken with them. Participants in both groups were instructed to try to appear innocent in the following polygraph examination.

A second experimenter, who was unaware of participants' condition, explained that the polygraph would be used to detect recognition of crime details. In line with previous research (Gustafson & Orne, 1963), motivational instructions on self-esteem were given: It was told that despite its high accuracy, intelligent people are able to beat the polygraph. Prior to the attachment of the electrodes, participants were requested to wash their hands. Once physiological recordings were attached, there were two phases before the concealed information test began. First, four visual stimuli (a seal, participant's own name, a bloody picture, and an erotic picture) and one auditory stimulus (white noise, 71 dB) were presented to optimize measurement of heart rate and skin conductance. Thereafter, all pictures ($n = 12$) that were to be presented in the concealed information test were displayed for 2,500 ms in random order. Participants were asked to simply look at all the pictures. This was done to diminish novelty ORs to the control stimuli during the test phase. Furthermore, this phase aimed to ensure that participants could discriminate crime from control pictures, enhancing the significance OR to the crime pictures.

Concealed Information Test. Participants were told that their primary task was to beat the polygraph by trying to conceal recognition of crime pictures. They were further informed in a cover story that we examined the effect of mental load on the validity of the polygraph. Therefore, they had to press the space bar on a standard keyboard as fast as possible whenever they heard a tone. The concealed information test started with a buffer item (picture of a pen). Thereafter, 24 pictures (12 of each crime) were presented in the middle of the screen during 2,500 ms, with interstimulus intervals (ISIs) from 15 to 25 s. The auditory probe was presented on half of the pictures, either 250, 500, or 750 ms after picture onset; the remaining half of the pictures were presented without probe ("unprobed"). Pictures were presented in one of four fixed semirandom orders, restricted by the following rules: (1) the first picture in each block was unprobed, (2) there could be no more than three consecutive probed (vs. unprobed) pictures, and (3) no more than three consecutive crime (vs. control) pictures. In addition to the probes presented during the pictures, there were 12 probes presented randomly during the ISI, but not within 5 s before or after a picture. Probe detection was practiced in 30 trials just before the concealed information test. A total of 24 reaction-time tones were presented during the concealed information test. Physiological recordings were obtained only during the probe-free trials. Finally, two digit trials (i.e., a random number between 1 and 10) were presented for 1 s during the ISI. Presentation was random, with the restriction that the digits were not displayed within 5 s before or after the pictures. To assure participants' attention was focused on the screen, they were asked to name these digits out loud.

Memory check. Immediately after the concealed information test, memory for crime pictures was assessed in a short classification task. Participants were asked to classify pictures truthfully as guilty or innocent by pressing the letter *s* for guilty (*schuldig* in Dutch) and the letter *o* for innocent (*onschuldig* in Dutch) pictures, respectively. The pictures for this rating task were presented at random one by one in the middle of the screen.

Scoring, response definition, and analysis. The results of three dependent variables are reported: second-by-second change in heart rate, magnitude of electrodermal responding, and probe response latency. The psychophysiological data were analyzed using Psychophysiolocal Analysis (PSPHA), a software program that we developed for the off-line analysis of psychophysiological data

PSPHA was used to detect the R-peaks and to calculate the distance between them. An artifact detection procedure was applied with PSPHA to detect erroneous detection and/or missing beats. The former was defined as IBIs less than 400 ms (150 bpm) or intervals that were shorter than 70% of the mean of the surrounding IBI. The latter was defined as IBIs greater than 1,500 ms (40 bpm) or intervals that were greater than 130% of the mean of the surrounding IBIs. The correction procedure consisted of splitting the prolonged IBIs and merging the shortened IBI to the previous IBI. Trials containing more than two corrected IBIs were excluded as artifacts. Ten IBIs (0.17%) needed correction and one trial was omitted from further analyses. Prior to analysis, the interbeat intervals (IBI) were converted to heart rate in beats per minute (bpm) per real-time epoch (1 s). Mean bpm in the 5 s preceding picture onset were compared to the mean bpm in the 5-s period after picture onset. The mean of the 5-s prestimulus period was subtracted from each poststimulus period, allowing a second-by-second analysis.

The maximal skin conductance change (with a minimum of 0.05 μS), starting between 1 and 5 s after picture onset, was analyzed. To normalize the data, they were square root transformed prior to statistical analysis.

Reaction times (RTs) were expressed as change scores (cf. Dawson, Schell, Beers, & Kelly, 1982). We subtracted the mean reaction time to probes during the intertrial interval from the mean reaction time on probes during pictures. A positive change score indicates a slower probe response on the pictures, compared to the mean reaction time during the intertrial intervals. A negative change score, indicates faster probe responding during the pictures.

A .05 significance level was employed in all statistical tests, and Greenhouse–Geisser corrections (with adjusted degrees of freedom) are reported where appropriate. As an estimate of effect size, the percentage of variance (PV) is reported. Following Cohen (1988), PVs of .01, .10, and .25 were used as thresholds to define the effects as small, medium, or large, respectively.

Results

Memory Check

Results of the memory check confirmed that the crime pictures were correctly recognized and remembered. Participants classified 99% of the pictures correctly.

Heart Rate

Prestimulus heart rate averaged 86 bpm. A 2 (picture: crime/control) × 5 (second: 1–5) multivariate analysis of variance (MANOVA) was used to analyze the heart rate data. There was a significant main effect of both second, $F(4,32) = 12.15$, $p < .05$, $PV = .60$, and picture, $F(1,35) = 4.16$, $p < .05$, $PV = .10$, confirming that a larger heart rate deceleration to pictures containing crime details ($M = -1.52$ bpm; $SD = 2.62$) as compared to control pictures ($M = -0.34$ bpm; $SD = 2.58$) was found (see Figure 1). There was no significant effect of Picture × Second, $F(4,32) = 1.75$, n.s.

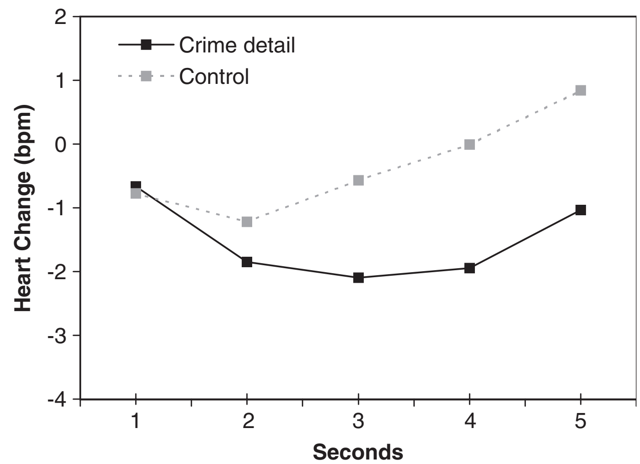

Figure 1. Effect of picture type (crime detail/control) on second-by-second change in heart rate (in beats per minute).

Skin Conductance

A paired t test was performed to compare the magnitude of the skin conductance response on crime and control pictures. This analysis revealed that crime pictures ($M = 1.19$, $SD = 0.19$) elicited larger responses than control pictures did ($M = 1.14$, $SD = 0.15$), $t(31) = 2.15$, $p < .05$, $PV = .15$.

Reaction-Time Data

RT data faster than 150 ms or slower than 2,000 ms were excluded from analysis (< 1% of the total data set). Mean RT on the probes during the ISI was 559 ($SD = 121$). RT change scores (RTC) were analyzed using picture (crime/control) and probe position (250/500/750) as within-subject variables in the ANOVA. This analysis revealed a significant main effect of probe position, $F(2,68) = 5.81$, $p < .01$, $PV = .15$, with greater RTC slowing in late compared to early probe positions. Furthermore, though RTCs at the middle and the late intervals were greater to crime compared to control pictures, neither the main effect of picture nor the Picture × Probe Position effect reached significance. Mean RTCs for the crime pictures were 43 ($SD = 147$), 29 ($SD = 139$), and -9 ($SD = 115$), respectively, at the early, middle, and late probe positions. For the control pictures, mean RTCs for the early, middle, and late probe positions were, respectively, 46 ($SD = 103$), 9 ($SD = 129$), and -26 ($SD = 124$).

Discussion

The present study investigated whether the detection of concealed information is based upon orienting or defensive responding. Using a concealed information test, participants who enacted a mock crime were presented with crime and control pictures while heart rate, skin conductance, and probe reaction times were measured. Although both the OR and the DR are associated with larger electrodermal responding and slowing of probe responding, these reflexes may be reliably differentiated by heart rate (Graham, 1979). Specifically, heart rate deceleration is taken as an index of orienting, whereas defensive responding is associated with heart rate acceleration.

Results of this study showed that crime pictures elicited greater heart rate deceleration than control pictures, supporting the orienting account. Direction, latency, and magnitude of this

cardiac change reflect typical orienting reaction (Graham, 1979; Öhman et al., 2000; Turpin, 1986). It should be noted that the present study is not the first to examine cardiovascular activity to concealed information. A few studies have measured heart rate to investigate whether it provides a valid index of concealed information (e.g., Bradley & Ainsworth, 1984; Bradley & Janisse, 1981; Podlesny & Raskin, 1978). These studies showed that, although better than chance level, heart rate was less effective than the skin conductance response in distinguishing guilty from innocent subjects. Given the theoretical scope of our research, the present study differs in two important aspects from these studies. First, whereas previous studies have only reported a global index of differential cardiac activity, we provided a second-by-second change in heart rate. Second, previous studies have presented crime and control items in a 1×4 proportion, leading to a confound of novelty and significance (Dawson, Schell, & Filion, 2000). That is, because the crime items are presented less often, relative novelty may contribute to the differential reactivity. Clearly this does not pose a problem in applied settings where one wishes to maximize the chance of differential responding. But, an equal number of crime and control pictures seems preferable when examining the underlying processes of enhanced responding to concealed information. Using this methodological setup, this study provided the opportunity to differentiate between orienting and defensive responding. As predicted, all pictures were accompanied by a decline in heart rate, and this deceleratory response was greater in crime compared to control pictures.

Skin conductance and reaction times were also obtained in this study. First, larger electrodermal responding to pictures containing crime details compared to control pictures was observed, thereby replicating previous studies. Although very large effects are typical in mock crime studies (an average Cohen's *d* of 2.09; Ben-Shakhar & Elaad, 2003), the present effect had an medium effect size. This finding corroborates the idea that relative novelty contributes to enhanced responding in the concealed information test. Second, we predicted that probe reaction times would be slower on crime pictures as compared to control pictures. Although results were in the predicted direction at the middle and the late probe positions, these differences failed to reach significance. Although this finding is at odds with previous studies using reaction times (Farwell & Donchin, 1991; Seymour, Seifert, Shafto, & Mosmann, 2000; Verschuere et al., in press), differences in methodology may account for the lack of significant findings. While several methodological differences can be listed, two seem most relevant. First, because we also measured autonomic measures, only a very small number of reaction-time trials was used. Increasing the number of trials might decrease both the variance in reaction times and the likelihood of reacting morer strongly to control stimuli. Second, whereas previous research has presented probes in the same sensory modality as the concealed information and control stimuli, we used auditory probes presented during visual stimuli. The use of different modalities might have reduced the interference effect in this study. Future research may examine the possibilities and boundaries of reaction times in the detection of concealed information.

Taken together, the present findings are in line with a cognitive explanation of enhanced responding to concealed information. The correct answers in the concealed information test are significant only to the knowledgeable subject. When such stimulus is detected, ongoing behavior is interrupted and attention is allocated to the significant stimulus. Different measures can and have been used to tap from this process of detection, interruption, and reallocation of attention. Thus, the cognitive view on orienting can integratively explain the increase in p300 amplitude, electrodermal responding, heart rate deceleration, reaction times, and pupil size in response to concealed information.

Despite the clear theoretical focus of this study, there are some potential practical implications. First, the present data further support the idea that the concealed information test is a theoretically sound polygraph technique (Ben-Shakhar et al., 2002). Second, an important critique of this test is the difficulty of creating a sufficient number of concealed information items. Lykken (1998) has argued that the use of pictures enlarges the flexibility of the concealed information test. The present study illustrates that modern technology makes it very easy to set up a pictorial version of the concealed information test. However, the validity of this pictorial variant remains to be tested. Third, the framing of the concealed information test in cognitive rather than emotional processes further enhances the applicability of the test. Although lying and motivation to deceive the test can enhance the efficacy of the concealed information test, they are not necessary conditions. This implies that there is no reason why this test would not be applicable in people with psychopathy. Psychopathic individuals are characterized by a marked emotional deficit, lacking empathy, anxiety, and feelings of guilt. Whereas this is exactly what traditional lie detection is based upon, the present data support the idea that the concealed information test is not conditional upon emotional distress. Furthermore, a recent review of the literature on autonomic responsivity in people with psychopathy (Arnett, 1997) showed that there is yet no evidence for reduced orienting in psychopathy. In contrast, it was hypothesized that psychopathy may be characterized by greater sensitivity to orienting stimuli. Thus, the present analysis leads us to conclude that a polygraph investigation using the concealed information test should work equally well, and perhaps even better, in people with psychopathy.

In the present study, we used a mock crime procedure under motivational instructions. Although this laboratory procedure resembles field situation most closely (Ben-Shakhar & Elaad, 2003), it remains different. With increasing threat, the physiological activation to crime stimuli might shift from orienting to defensive action. Lang et al. (1997) theorized that the difference between orienting and defense is not dichotomous, but rather that it is dynamically related to the aversiveness of stimulation. At a low aversive stimulation level, more attention is given to novel/significant stimuli compared to known/neutral stimuli. This is the typical OR, producing distinct autonomic changes, among which are heart rate deceleration and an increase in skin conductance responding. With increasing levels of threat, orienting transits to defensive activation to prepare an organism for basic fight/flight responses. Similarly, the nature of physiological responding during a polygraph examination may depend on the arousal value of the relevant items. Raskin (1979) reasoned that defensive responding can be expected to occur in polygraph tests consisting of direct, accusatory questions (e.g., control question technique), but is less likely in the concealed information test. However, given the highly threatening nature of the crime stimuli in a real-life, high-stakes criminal investigation, one might expect defensive responding. In each case, it seems worthwhile to examine whether physiological responding to concealed information follows the defensive cascade from the laboratory to the field.

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